AMERICAN MUSEUM NOVITATES

Number 871 Published by THE AMERICAN MUSEUM OF NATURAL HISTORY New York City July 6, 1936

COMPARATIVE ANATOMY OF THE SOLE OF THE FOOT

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During the preparation of an exhibit for the Hall of the Natural History of Man in The American Museum of Natural History comparative dissections of the muscles of the sole of the foot in man, the gorilla, the chimpanzee and the bear were made. The bear was included in the series because of its more or less primitive pentadactyl foot, also on account of its size and because it has been compared in the past with the foot of man, which it was said to resemble.

The bear is commonly referred to as plantigrade, but an examination of the exterior of the bear's sole (Fig. 1A) reveals that the bare skin does not reach nearly to the heel and that in walking the heel and proximal part of the foot do not come in contact with the ground unless the latter be very soft. The accompanying illustration shows the proportion of the sole occupied by bare skin and hair. It will be noticed that this bear's pad is very similar to that of a dog, but more elongate. The figure on the right (Fig. 1B) is a sketch by Ernest Thompson Seton of the foot print of a bear. This clearly shows that the heel does not come in contact with the ground. Thus as only a portion of the plantar surface of the foot comes in contact with the ground during locomotion, or when standing on all fours, or erect, the animal can not, in a strict sense, be termed plantigrade.

A superficial examination of the toes of this series of animals immediately reveals the fact that in the bear the first digit or hallux is the shortest, whereas in the anthropoid apes it is larger than any other digit. Its greatest size is attained in man. In other carnivores, i. e., the dog, the hallux has been entirely eliminated as a functional digit.

SUPERFICIAL LAYER.—In the four forms dissected, upon removal of the skin of the sole a fatty pad is found to cover the entire under side of the foot in man and the anthropoids, whereas in the bear a fatty pad is limited to the area covered by bare skin. In dissection of the superficial layer of muscles it was found that the plantar aponeurosis in the bear was fused with the M. flexor digitorum brevis, whereas in the anthropoids and man they were quite distinct.

Figure 2 shows the appearance of the dissections after removal of skin, pad and plantar aponeurosis.

Reading from left to right, this series indicates the progressive evolution of the flexor digitorum brevis from an almost ligamentous condition in the typical mammal to the powerful muscle of the primates, including man.

The hallux is weak in the bear, very strong in the primates, culminating in man.

Fig. 1. A. Plantar surface of left hind foot of young bear (*Euarctos americanus*).

Fig. 1. B. Sketch of bear track, right hind foot. After Ernest Thompson Seton, 'Life Histories of Northern Animals: An Account of the Mammals of Manitoba,' II, Fig. 247 C. 1909. Courtesy of the author and Charles Scribner's Sons, New York.

SECOND LAYER.—In this series (Fig. 3) it will be seen that the bear contrasts with all the others in the following characters:

	BEAR	MAN AND ANTHROPOIDS
Flexor tendons of digits	Fan-like	Outer four grouped; tendon of big toe offset
Abductor digiti quinti	Very small	Large
Flexor digitorum brevis, proximal end	Thin and tendinous	Thick and fleshy
Origin of abductor hallucis	Not from heel	From heel

Thus man has retained the anthropoid arrangement for spreading the inner and outer toes.

THIRD LAYER.—In the third layer (Fig. 4) it will be seen that in the bear none of the muscles are specialized abductors of the hallux, as they are in the anthropoids and man. In man the transverse head of the adductor hallucis is secondarily reduced, the great toe being held to the others mainly by the transverse ligaments. The oblique head of the adductor is powerfully developed.

FOURTH LAYER.—In the fourth layer (Fig. 5) we see that in the bear all the digits retain the radiating arrangement, but in the anthropoids and man there is a deep cleft between the first and second digits. In the anthropoids and man also the tendon of the peroneus longus is almost in line with the first metatarsal.

In the anthropoids and man the proximal end of the heel bone is turned downward. On the other hand, man has advanced beyond the anthropoids in that the great toe has grown longer, the outer four toes shorter.

DEEP TRANSVERSE PLANTAR LIGAMENT.—Wood Jones (1929, pp. 312, 313) has objected to the suggested derivation of the human foot from any known anthropoid partly on the grounds that in man the hallux is "directed in line with its fellows," whereas in anthropoids it is "abducted from its fellows" and that the human hallux is "firmly bound to the metatarsals of the remaining digits by the powerful transverse metatarsal ligament," while the anthropoid hallux is "largely free of the integumentary covering of the foot, so that it appears to arise a long way back along the inner side of the foot" and its "metatarsal is exempt from the bond of the transverse metatarsal ligament."

With regard to the difference in the normal position of the hallux in man and anthropoids, Schultz (1924, 1926) has shown that this difference is much less in foetal than in adult stages and he concludes that in man "the great toe has become strengthened and adduced, both phylogenetically and ontogenetically. . ."

With regard to the transverse metatarsal ligament, the presence of this structure, or at least of its morphological antecedents, does not prevent the metatarsal of the hallux from being considerably abducted in early human foetal stages (Schultz, 1926, p. 497). Thus this ligament must be relatively shortened between early foetal and adult stages.

Wood Jones' too diagrammatic figure (148) of the plantar surface of an anthropoid ape's foot indicates a complete lack of connecting tissue between the head of the metatarsal of the hallux and that of the second

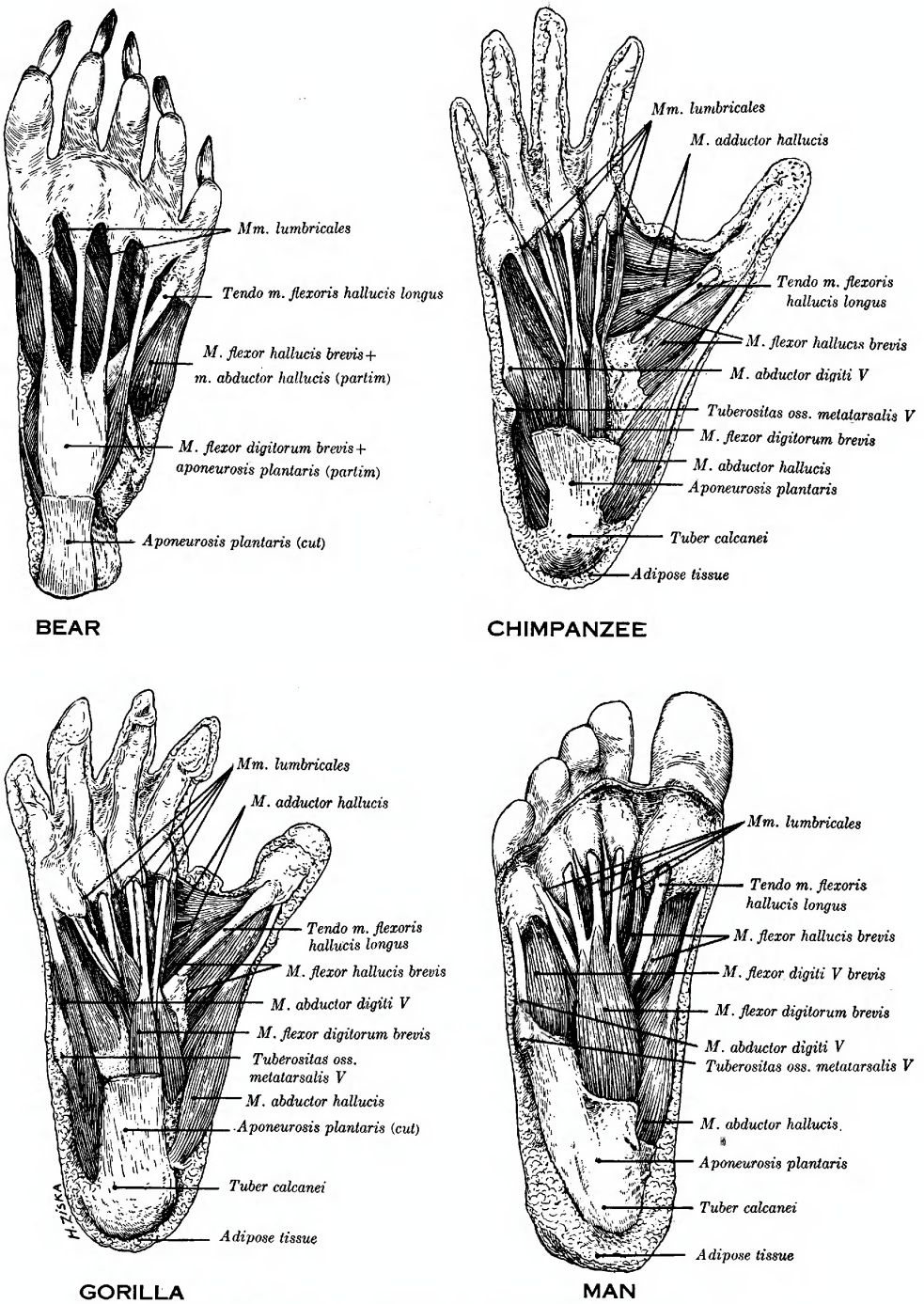


Fig. 2. Dissections of plantar musculature, superficial layer.

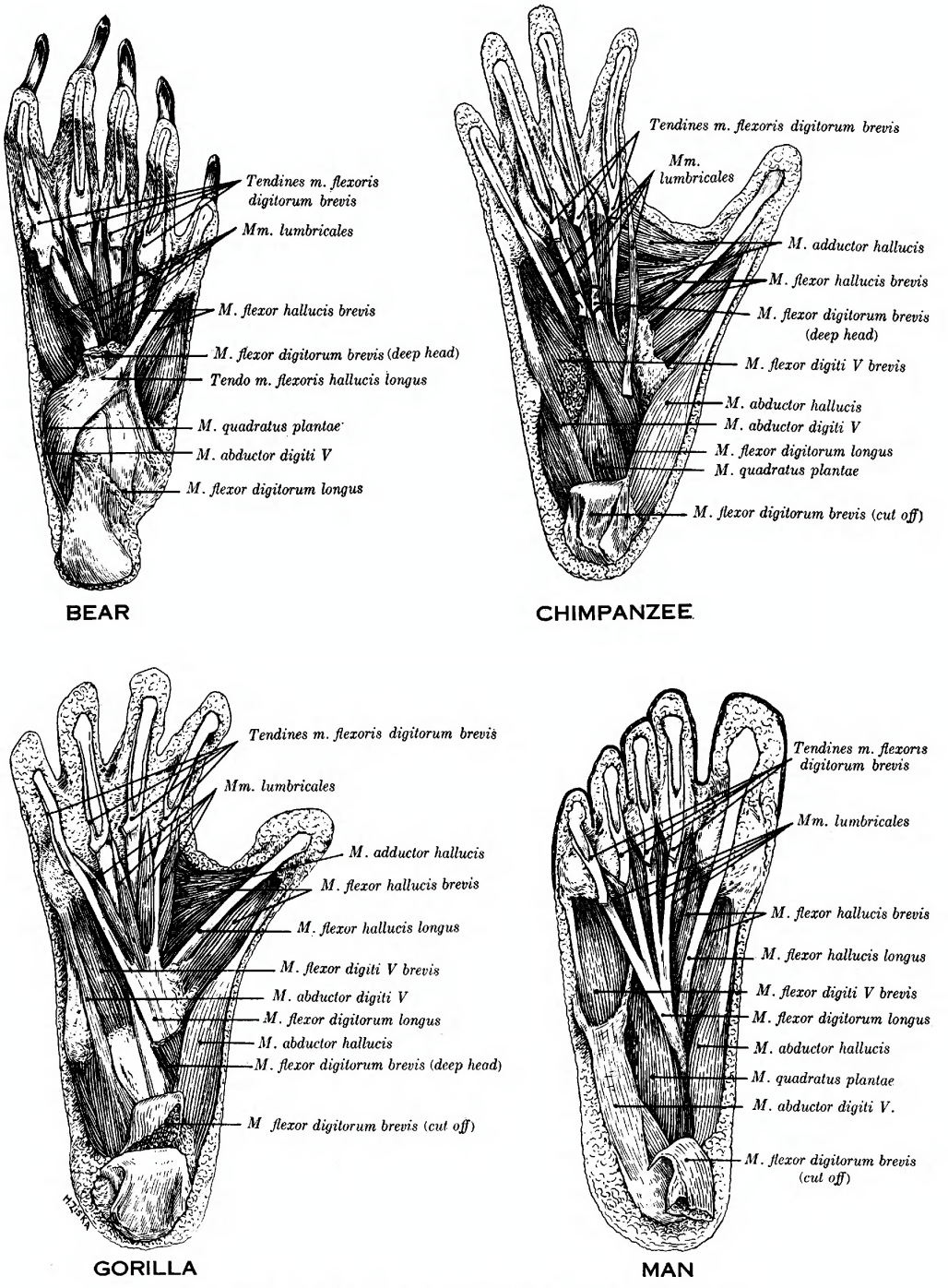


Fig. 3. Dissections of plantar musculature, second layer.

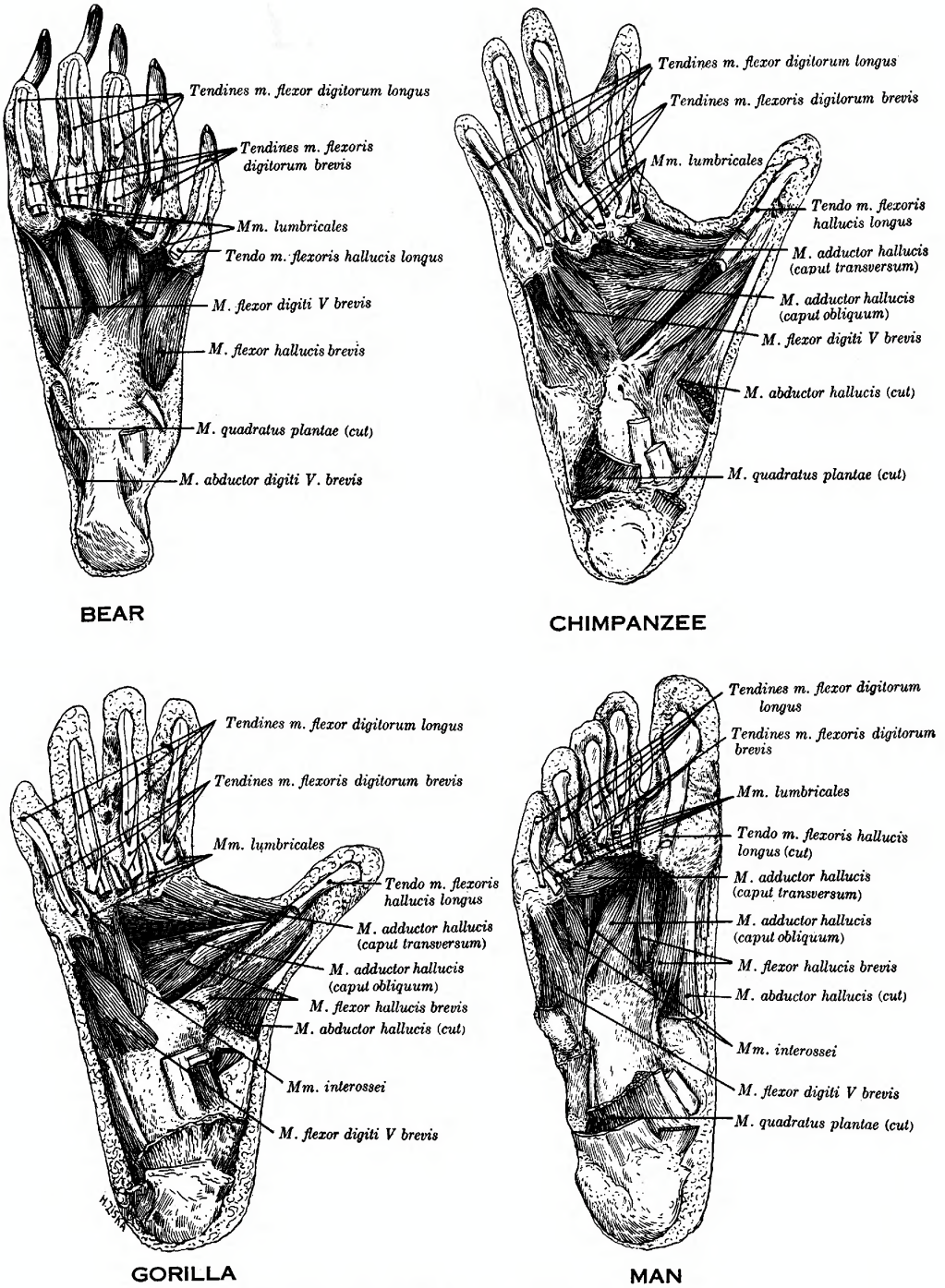
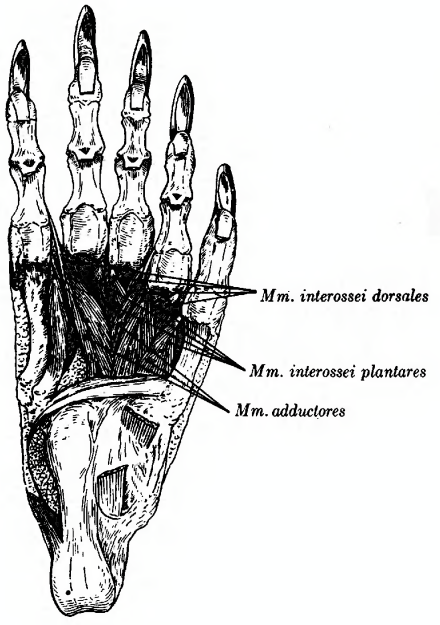
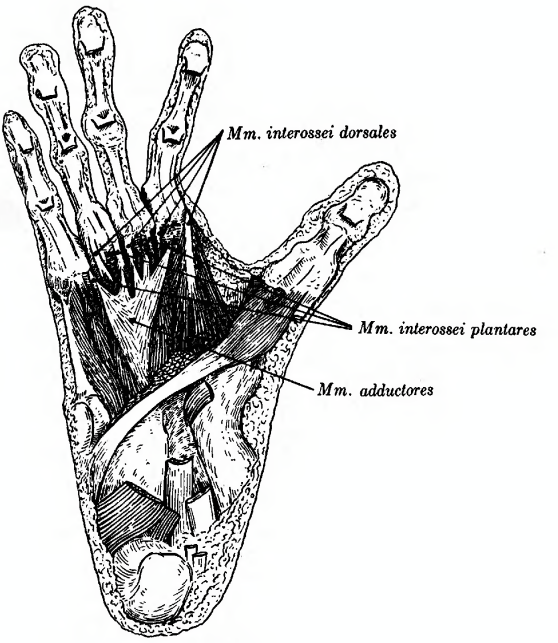

Tendines m. flexor digitorum longus
Tendines m. flexoris digitorum brevis
Mm. lumbricales
Tendo m. flexoris hallucis longus
M. flexor digiti V brevis
M. flexor hallucis brevis
M. quadratus plantae (cut)
M. abductor digiti V. brevis
BEAR
Tendines m. flexor digitorum longus
Tendines m. flexoris digitorum brevis
Mm. lumbricales
Tendo m. flexoris hallucis longus
M. adductor hallucis (caput transversum)
M. adductor hallucis (caput obliquum)
M. flexor digiti V brevis
M. abductor hallucis (cut)
M. quadratus plantae (cut)
CHIMPANZEE
Tendines m. flexor digitorum longus
Tendines m. flexoris digitorum brevis
Mm. lumbricales
Tendo m. flexoris hallucis longus
M. adductor hallucis (caput transversum)
M. adductor hallucis (caput obliquum)
M. flexor hallucis brevis
M. abductor hallucis (cut)
Mm. interossei
M. flexor digiti V brevis
GORILLA
Tendines m. flexor digitorum longus
Tendines m. flexoris digitorum brevis
Mm. lumbricales
Tendo m. flexoris hallucis longus (cut)
M. adductor hallucis (caput transversum)
M. adductor hallucis (caput obliquum)
M. flexor hallucis brevis
M. abductor hallucis (cut)
Mm. interossei
M. flexor digiti V brevis
M. quadratus plantae (cut)
MAN

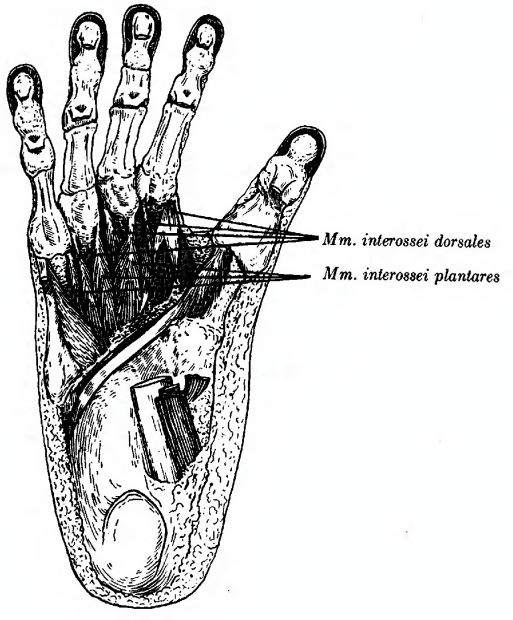
Fig. 4. Dissections of plantar musculature, third layer.



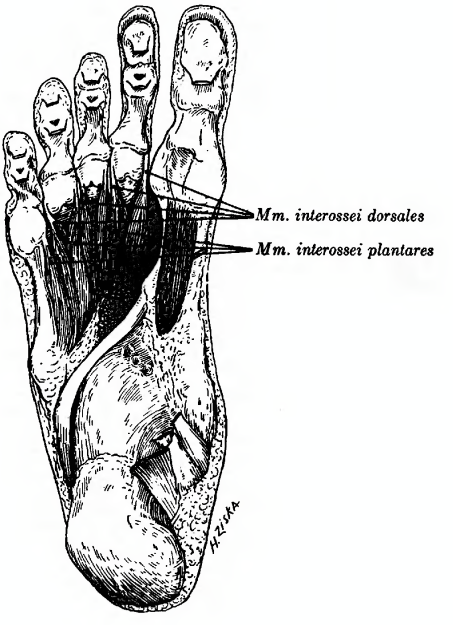
BEAR



CHIMPANZEE



GORILLA



MAN

Fig. 5. Dissections of plantar musculature, deep layer.

digit. But in my dissections of the feet of chimpanzee and gorilla I found, first, that the caput transversum of the adductor hallucis muscle (Fig. 4) extends across the region where there is nothing but a deep cleft in Wood Jones' diagram, and secondly, that there is a strong fascial covering distal to this muscle, which connects the transverse metatarsal ligament of the other digits with the hallux. This transverse fascial band (Fig. 6) is in the same relative position as the hallucial portion of the transverse metatarsal ligament of man and needs only to be shortened and thickened to give rise to the human condition.

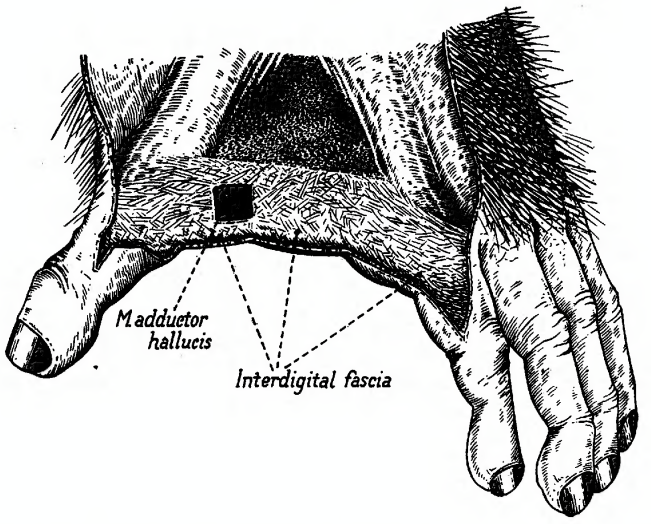


Fig. 6. Foot of chimpanzee showing relations of tissues between first and second metatarsals.

CONCLUSION

The dissections described above should refute the old idea that the foot of the bear shows any close morphological resemblance to that of man. The same series indicates clearly that with regard to the musculature of the sole of the foot the human arrangement is derivable from a primitive anthropoid type by comparatively minor morphological adjustments during the change from arboreal to bipedal habits.

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